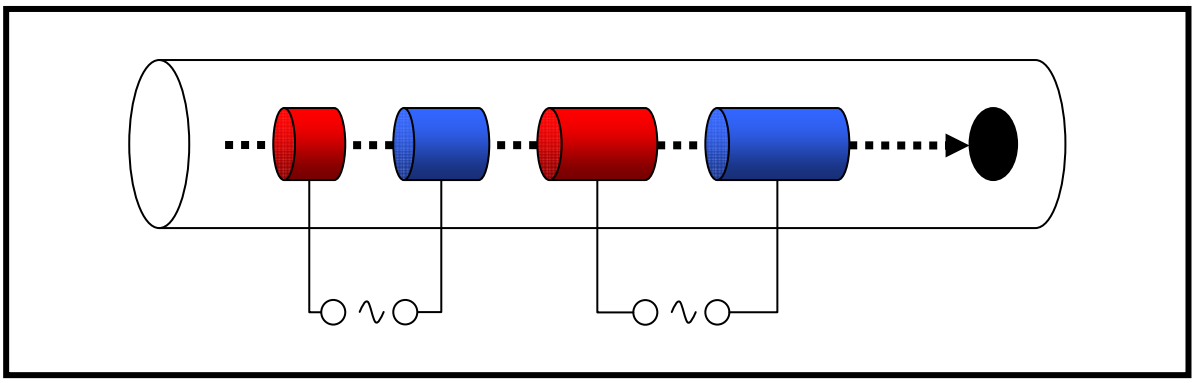
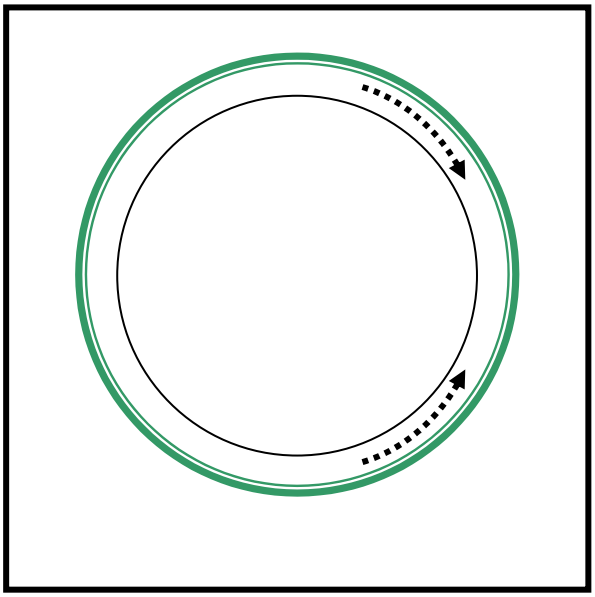
Linear Accelerators



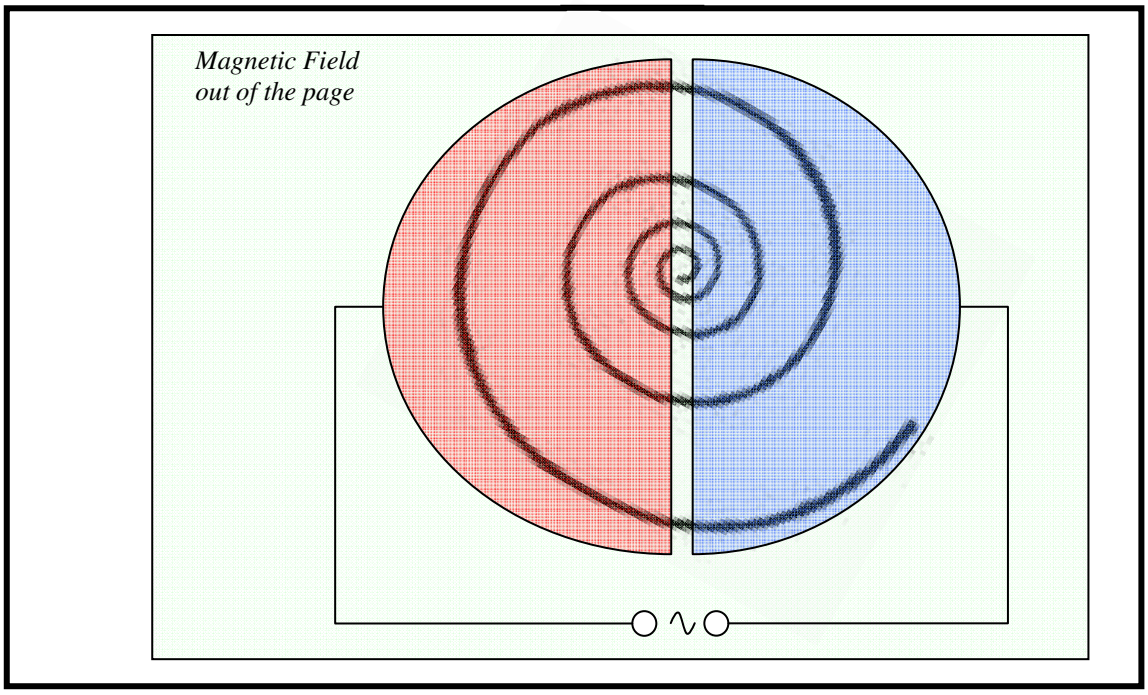
- A linear accelerator is a long straight vacuum tube containing a series of pipe-shaped electrodes of increasing length.
- Alternating current is applied to neighbouring electrodes so that the charge on them continuously changes.
- The alternating current is timed with a frequency such that the source particle is always attracted to the next electrode and repelled from the previous one.
- The electrodes are of increasing length so that the frequency at which the charge changes can be constant despite the increased velocity of the particle as it makes its way down the accelerator.
- Each time a particle passes through an electrode it is accelerated by the electric field. In this way with a long enough accelerator particles can approach the speed of light.
- The high energy particles are then collided with a fixed target at the end of the accelerator.

Synchrotrons



- Circular accelerators work in a similar way, using alternating electrodes to accelerate a charged particle.
- A circular accelerator uses electromagnets to guide the particles around the circle.
- In a Synchrotron rather than having variable length electrodes and a fixed frequency of alternation, a supercomputer is used to control the alternations
- This allows particles to go round the accelerator many times, and allowing more than one particle through the accelerator at the same time (for high energy collisions).

Cyclotron



- A cyclotron uses two semicircular electrodes called "dees" to accelerate charged particles across the gap between them.
- An alternating potential difference is applied between the electrodes, attracting the electrode to the opposite dee. As the particles cross the gap they are accelerated by the electric field between the electrodes.
- A strong magnetic field keeps the particles moving in a circle, causing the rules of circular motion to be applied to the accelerating particle.
- The combined effects of the magnetic and electric fields cause the particle to spiral outwards as their energy increases.
- This system can be used to provide a continuous stream of particles (unlike other accelerators which can only deal with bursts of particles at a time).
- A single frequency of alternation is needed for the power supply since the time taken to cross each dee is constant and the frequency does not depend on either the velocity or the radius.. (Shown below)

$$\text{Centripetal Force} = \text{Magnetic Force}$$

$$BQv = \frac{mv^2}{r}$$

$$\frac{v}{r} = \frac{BQ}{m}$$

$$\omega = \frac{BQ}{m}$$

$$2\pi f = \frac{BQ}{m}$$

$$f = \frac{BQ}{2m\pi}$$

- A limitation of the cyclotron is that as the speed of light is approached and relativity requires the mass of the particle to increase rather than the velocity the time taken to cross each dee will no longer be constant, requiring an overly complicated computer controlled frequency of alternation.